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Chapter 2 Climate

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Climate

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Introduction

The broad climatic patterns of the Sand Hills region are also characteristic of the central Great Plains environment. The spatial and temporal patterns of these climatic variables have a significant effect on the natural resources of the region.

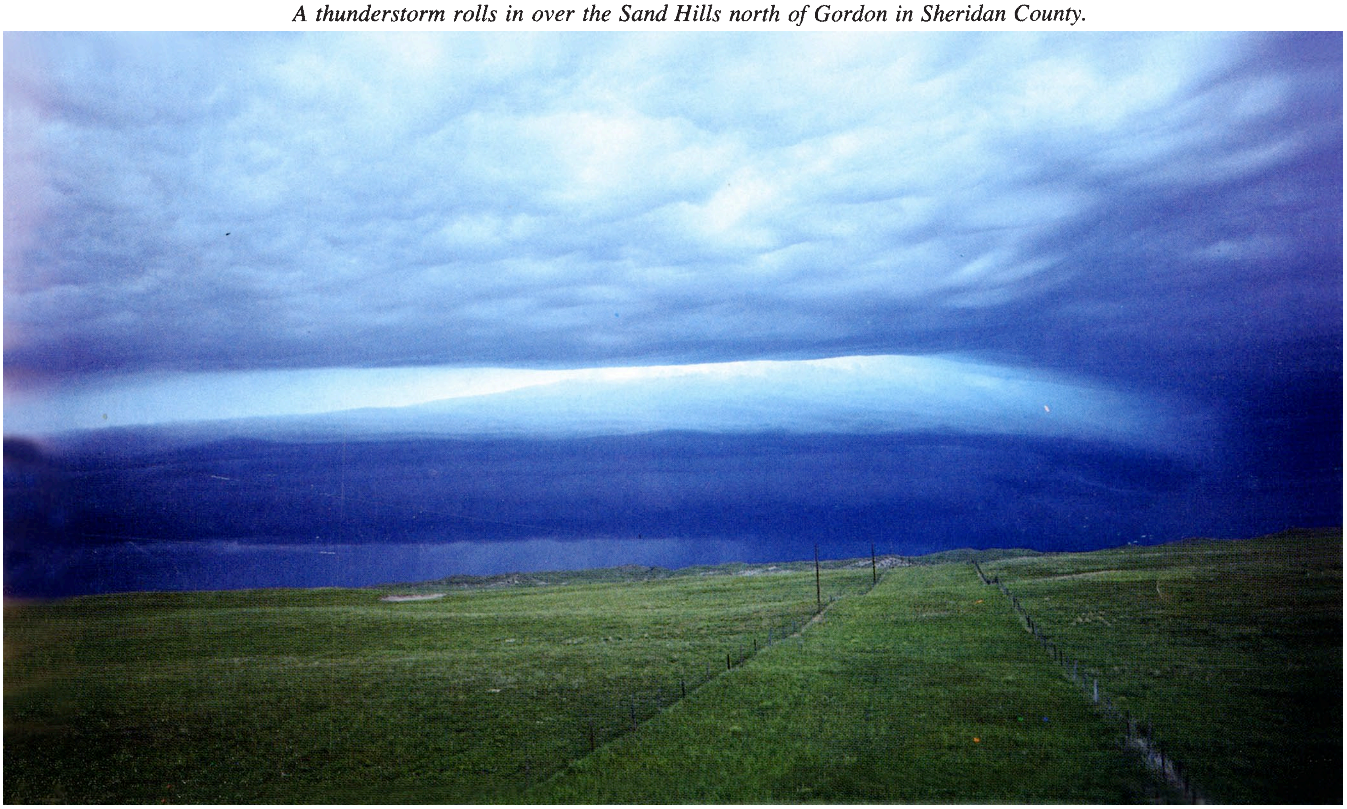
Precipitation

Precipitation in the Sand Hills ranges from an average annual total of 23 inches in the east to slightly less than 17 inches in the extreme west (fig. 2-1). This decline from east to west is the result of a combination of factors: 1) Nebraska's interior location; 2) the blocking effect of the Rocky Mountains on moisture from the Pacific Ocean; and 3) increasing distance from the Gulf of Mexico, the region's primary source of moisture. (North-to-south variation in precipitation is negligible.)

Table 2-1 includes data on average precipitation and temperature for five Sand Hills stations. Approximately 75 percent of the average annual precipitation occurs during the April-to-September growing season (fig. 2-2), about 50 percent falling during May, June, and July. In spring and early summer, precipitation in the Sand Hills is greater than at any other time of year, primarily because of the frequency of cyclonic (low-pressure) disturbances. As the summer progresses, these principal storm tracks shift farther to the north, causing less rainfall in July and August. In these months, convection (warm air rising and clouds forming) is responsible for most of the rainfall, although rainfall is often associated with weak frontal passages (the boundary between two air masses of different temperature). Therefore, rainfall amounts during July and August may differ radically within short distances. The number of days with precipitation of half an inch or more ranges from about 14 in the eastern Sand Hills to 10 in the west (Lawson and others, 1977).

Winter precipitation (October-March) is usually snow. Short periods of thawing and freezing are characteristic of the Sand Hills. Water resulting from the melted snow will cause an increase in the stored soil moisture and possibly raise the water table. In spring the soil moisture serves as an important source of water for early plant growth. The average annual accumulation of snowfall ranges from 22 to 28 inches along both the southeastern and southern margins to 45 inches in the north, near Nenzel and Ainsworth. Snow density (the percentage of a volume of snow that its water equivalent would occupy) varies from east to west. Snow is somewhat drier and more susceptible to blowing in the west. Winter precipita-

A thunderstorm rolls in over the Sand Hills north of Gordon in Sheridan County.



James Swinehart

tion is also generally associated with outbreaks of cold polar air masses.

The importance of the right amount and kind of snowfall in the Sand Hills to crops and livestock is four-fold. First, since evaporation rates are lower in winter, snow provides a source of moisture to recharge the soil profile and groundwater. This moisture is then available for plant growth in the spring. Second, snow helps protect the sand from wind erosion by providing a temporary cover during winter storms. Third, when snowfall is heavy, especially if accompanied by freezing rain or sleet, it becomes extremely difficult for cattle to graze. Finally, high winds and snowfall often occur together, and the resulting blizzards are a potentially dangerous natural hazard. (A blizzard is a weather condition with mean windspeeds of at least 35 miles per hour, considerable falling and/or blowing snow, and temperatures of 20 degrees F or less over an extended period.) Not only do freezing temperatures and blowing snow take their toll on mature cattle, but if these blizzards occur during the spring calving period, losses can reach disastrous proportions. In an average year, more than a half million calves are born in the Sand Hills (Nebraska Department of Agriculture, 1984).

The frequency of blizzards in the United States is shown in figure 2-3. Note the concentration of blizzards in the Great Plains region, extending from the Canadian border through the Sand Hills to central Kansas. The Sand Hills experienced from 12 to 16 blizzards in the 100-year period from 1871-1971 (Wilson, 1974). Blizzards are most common in the spring, particularly March and April, and the area most affected is depicted in figure 2-4.

The probability of receiving significant amounts of precipitation varies widely from month to month and from season to season for all Sand Hills and Nebraska locations. For example, from mid-November to mid-March, the probability of receiving 1 inch of precipitation in a 1-week period is near zero (Shaw and others, 1960). From mid-March until early May, the probability increases to about 25 percent and remains stable until the third week in June. The probability then decreases gradually throughout the late summer and fall months, approaching zero after mid-November.

Whether analyzed on a monthly or annual basis, Nebraska's precipitation is seldom average. High variability is one of the most significant characteristics of the state's precipitation patterns. Total annual precipitation for Ewing and Valentine for the period 1900-1985 is shown in figure 2-5. Annual precipitation totals at Ewing exhibit high variability during this time, ranging from a maximum of 37.80 inches in 1951 to a minimum of 12.48 inches in 1936. For Valentine, the range is from 28.91 inches in 1929 to 10.57 inches in 1974. The dry period of the 1930s is especially evident in this graph.

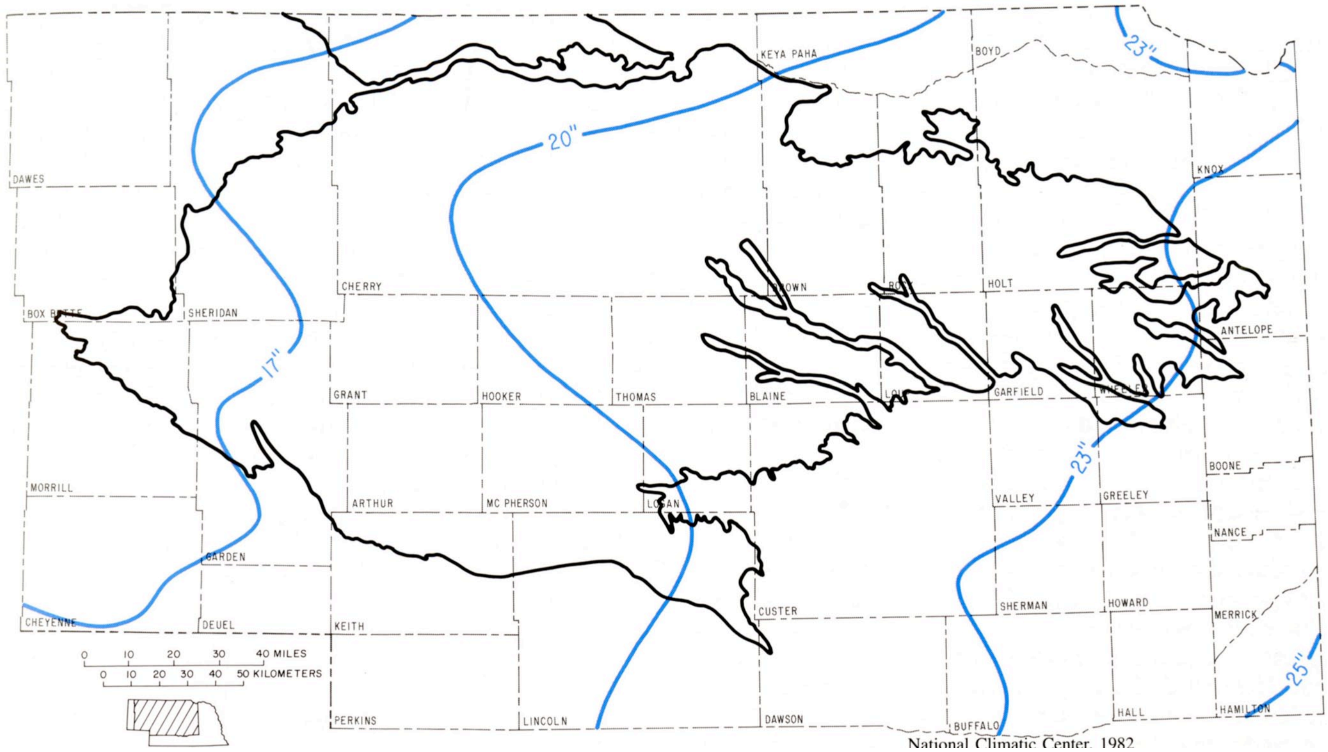
Drought

The Palmer Drought Severity Index is a commonly used measure of the meteorological severity of drought in the United States. This index depicts the relative wetness (+) or dryness (-) of an area compared to average conditions, and

Table 2-1. Average monthly and annual precipitation and average maximum, minimum, and mean monthly and annual temperatures for five Sand Hills locations. Normals are the period 1951-1980. Temperature is expressed in degrees F. Precipitation is expressed in inches. (Source: U.S. Weather Bureau)

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
O'Neill													
Precip.	.41	.68	1.28	2.41	3.32	4.00	3.38	2.54	2.09	1.32	.78	.62	22.83
Temp: Max	29.6	36.0	44.9	61.3	72.5	82.3	88.5	86.7	76.7	65.3	47.3	35.2	60.5
Min	7.8	13.9	21.8	35.1	46.5	56.2	61.6	59.7	49.4	37.7	24.0	13.7	35.6
Mean	18.7	24.9	33.4	48.2	59.5	69.2	75.1	73.2	63.1	51.6	35.7	24.5	48.1
Arthur													
Precip.	.31	.31	.76	1.71	3.38	3.46	3.29	2.00	1.62	.87	.49	.33	18.53
Temp: Max	35.5	41.5	47.9	61.0	70.9	80.6	87.3	85.6	76.8	65.8	49.1	39.8	61.8
Min	8.7	13.9	19.8	31.5	42.8	52.7	58.4	56.3	46.3	34.3	20.6	13.1	33.2
Mean	22.1	27.8	33.9	46.3	56.9	66.7	72.9	71.0	61.6	50.1	34.9	26.5	47.6
Purdum													
Precip.	.43	.74	1.17	2.27	3.38	3.34	3.01	2.46	1.76	.97	.64	.51	20.68
Temp: Max	34.6	40.5	47.9	62.4	73.0	82.9	89.0	87.0	78.2	67.4	49.6	39.4	62.7
Min	8.9	14.3	21.4	33.7	44.6	54.5	60.0	57.8	47.6	35.7	22.4	13.8	34.6
Mean	21.8	27.4	34.7	48.1	58.9	68.7	74.5	72.4	63.0	51.6	36.0	26.6	48.6
North Loup													
Precip.	.43	.72	1.34	2.31	3.50	3.65	3.17	3.24	2.29	1.29	.63	.56	23.13
Temp: Max	33.0	39.7	48.2	63.5	73.6	83.2	87.8	86.0	77.3	67.3	50.1	38.6	62.4
Min	8.8	14.8	23.3	35.8	47.3	7.5	62.7	60.5	50.2	37.6	24.0	14.3	36.4
Mean	20.9	27.3	35.8	49.7	60.5	70.4	75.3	73.3	63.7	52.5	37.1	26.5	49.4
Merriman													
Precip.	.40	.56	.90	1.98	2.69	3.47	2.43	1.83	1.27	.85	.41	.39	17.18
Temp: Max	34.1	40.1	46.3	59.9	71.3	81.0	88.6	87.4	78.1	66.5	48.5	38.4	61.7
Min	8.7	14.4	20.8	32.1	43.4	53.0	58.8	56.4	46.1	35.3	22.1	14.0	33.8
Mean	21.4	27.3	33.6	46.0	57.4	67.0	73.7	71.9	62.1	50.9	35.3	26.2	47.7

Sand Hills boundary is bold black line.



National Climatic Center, 1982

Fig. 2-1. Average annual precipitation, 1951-1980.

Sand Hills boundary is bold black line.

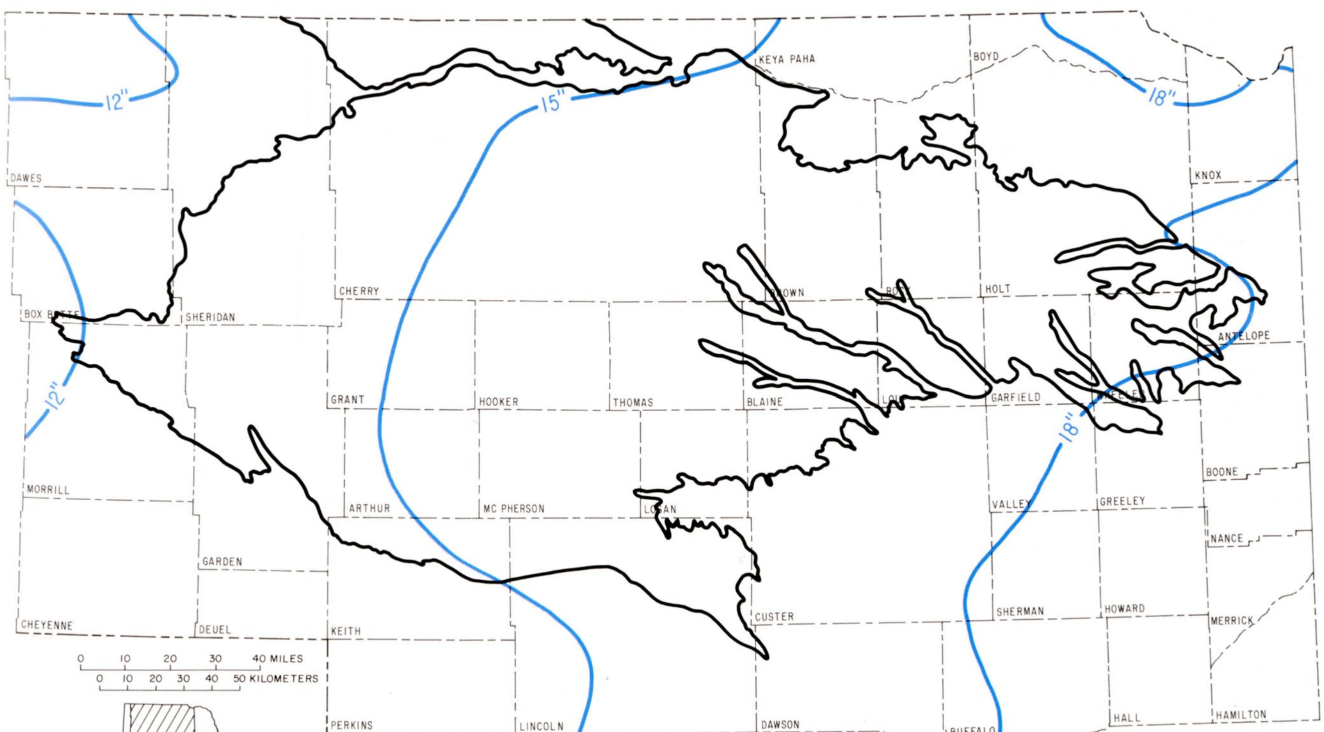


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Fig. 2-2. Growing season precipitation, 1951-1980.

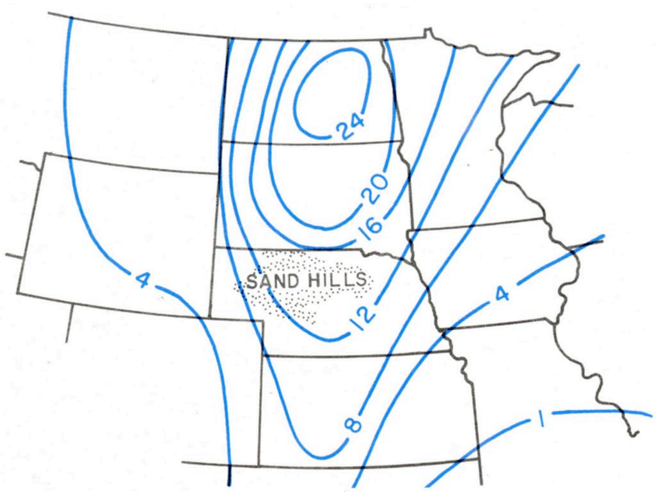


Fig. 2-3. Number of blizzards, 56 cases—1871 to 1971 (from Wilson, 1974).

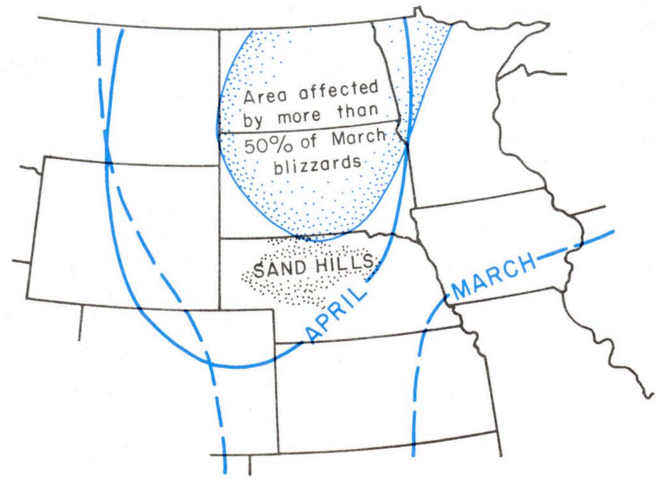


Fig. 2-4. Area affected by blizzards during March and April (from Wilson, 1974).

Cattle feeding in the snow

takes into account precipitation, runoff, soil recharge, deep percolation, and evapotranspiration. Figure 2-6 presents a plot of Palmer Index values for the Sand Hills. Note the wide range of index values, from a high of +7 in the early 1950s to about -7 in the 1930s. The large fluctuations on this graph are evidence of the variability of moisture conditions in the region; in particular, the negative indices in the 1930s and the mid-1950s show two major long-term drought episodes.

The Sand Hills historically have been less vulnerable to the impacts of droughts than have other parts of Nebraska. This is because the Sand Hills have been left largely in native vegetation, and such plants are well adapted to the vagaries of climate. Vulnerability is also decreased because of the existence of a large groundwater reservoir, which (among other things) stabilizes streamflows, provides water to numerous lakes

Drying pond near the border of Loup, Rock, and Brown counties

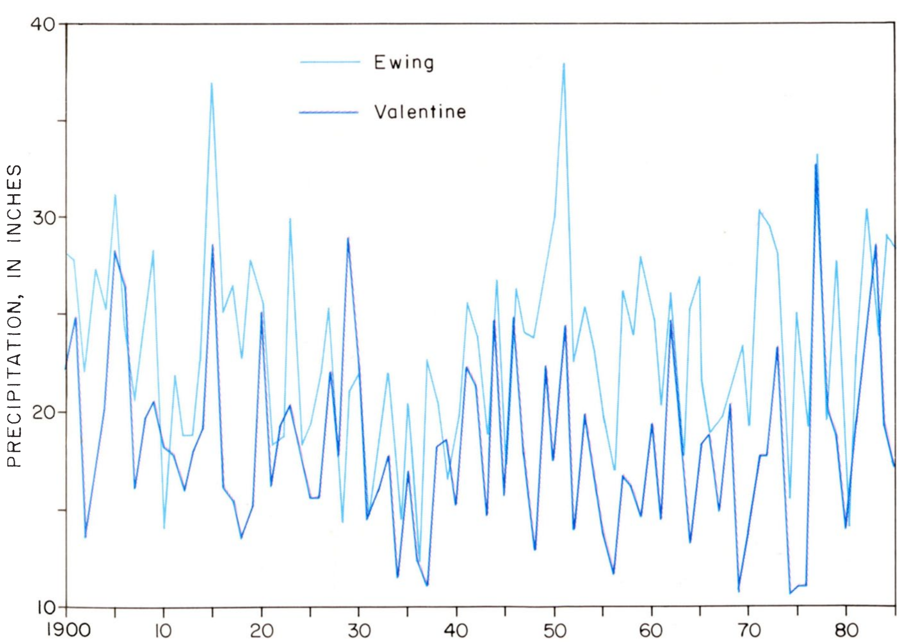


Fig. 2-5. Annual precipitation for Ewing and Valentine, 1900-1985.

and subirrigated meadows, and serves as a source of irrigation to supplement and stabilize forage supplies for the region's livestock industry and wildlife.

Temperature

Temperature gradients are similar to precipitation gradients, with a greater magnitude of change from east to west than from north to south. Average annual temperatures range from 49 degrees F in the east to slightly less than 48 degrees F in the west. This tendency toward cooler temperatures in the west becomes most noticeable in the summer months, with the mid-summer mean (June, July and August) showing a 3-degree F difference between the northeast and southwest portion of the Sand Hills (table 2-1). Mean temperatures in summer are generally in the upper 60s to mid-70s.

Average winter temperature in the region for the 6-month period of October-March is about 32 degrees F. Temperatures are slightly higher for the western counties during this period. Mean temperatures for January (the coldest month) range from 20.3 degrees F in the northeast to 24.2 in the southwest.

Average maximum and minimum temperatures do not exhibit the same pattern as average temperatures in the Sand Hills. A look at January maximum temperatures reveals that they range from about 30 degrees F in the northeast to slightly less than 38 degrees F in the southwest (fig. 2-7). The pattern of min-

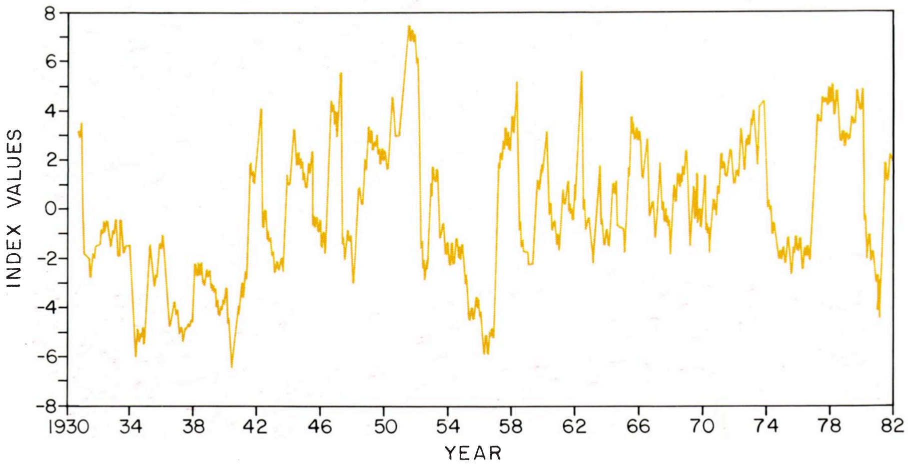


Fig. 2-6. Palmer Drought Severity Index for the Sand Hills, 1931-1982, by month. Data from National Climatic Center, Asheville, North Carolina.

imum temperatures is similar, ranging from 7 degrees F in the northeast to slightly less than 11 degrees F in the southwest. In July, this pattern is reversed (fig. 2-8). Daily maximum values range from about 90 degrees F in the southwest to about 88 degrees F in the northeast. Minimum values range from 58 degrees F in the west to about 62 degrees F in the southeast. The range of daily maximum and minimum values across the region is considerably greater in winter than in summer.

The length of the freeze-free season (the average number of days between the last spring freeze and the first fall freeze) is greater in the east (fig. 2-9). The freeze-free season ranges from about 150 days in the east to about 120 in the northwest (Neild, 1977). This pattern is the result primarily of the elevations in the west (4,000 feet), which are about 2,000 feet higher than eastern elevations.

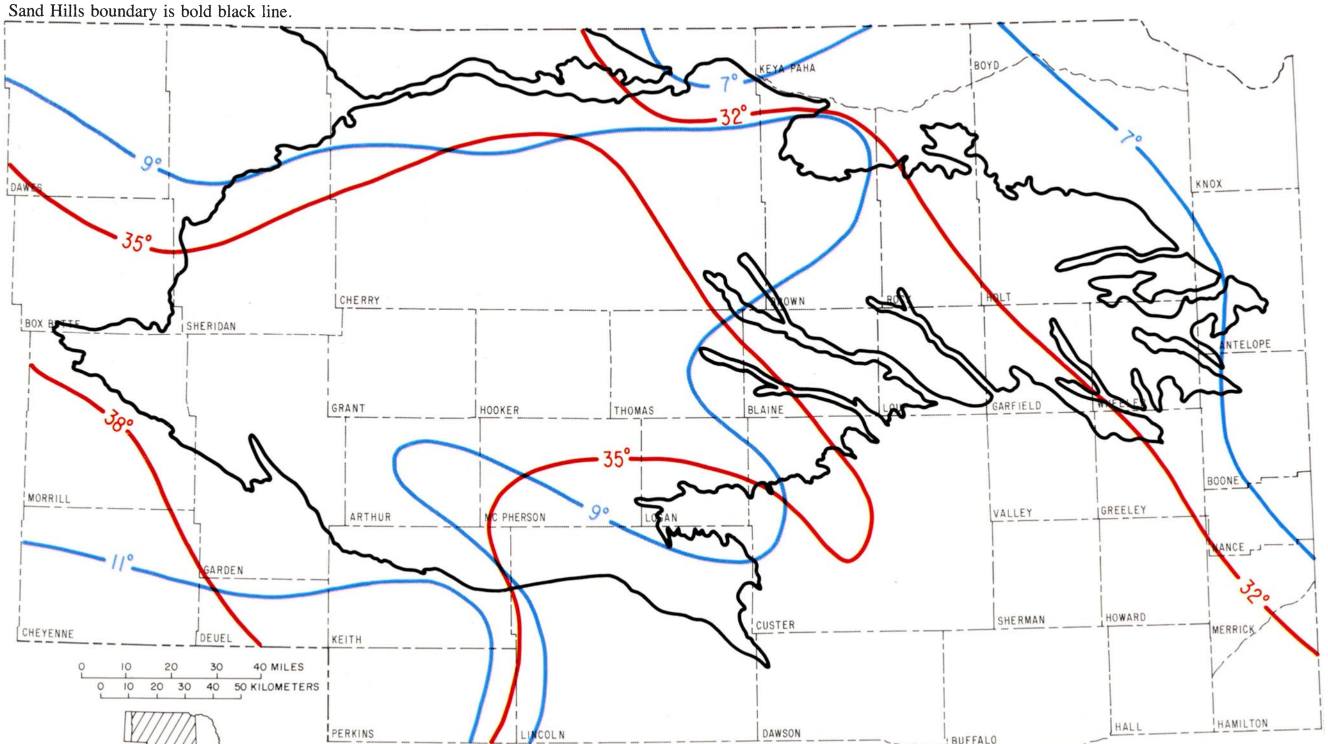
The probability of a light, moderate, or heavy freeze for Valentine in the north-central Sand Hills is shown in figure 2-10 (Neild and Webb, 1973). Light, moderate, and heavy freezes are defined by the occurrence of temperatures of 32-29 degrees F, 28-25 degrees F, and 24 degrees F or lower, respectively. For Valentine, the probabilities of light, moderate, and heavy freezes on or after April 29 are 80 percent, 42 percent, and 13 percent, respectively. The probabilities of light, moderate, and heavy freezes on or before October 10 are 84 percent, 50 percent, and 18 percent, respectively.

The concept of growing degree days (GDD) was developed as an indirect measure of plant growth in relation to temperature. Below a certain temperature (the base temperature), no growth occurs. Above the base temperature the growth rate is proportional to temperature.

Thus, the development time between critical plant growth stages is related to temperature during the growing season. Figure 2-11 depicts a pattern of GDD accumulations ranging from about 2,800 in the southeast to about 2,200 in the extreme northwest (Neild, 1977). The base temperature is 40 degrees F for cool-season crops (wheat and oats). Warm-season crops respond above a base temperature of 50 degrees F. The pattern illustrated in figure 2-11 is for growing degree days with a 50-degree F base temperature. Corn is usually planted around May 15 in the eastern Sand Hills and requires about 2,450 GDD to reach maturity.

An analysis of sunshine data by Rosenberg (1964) has shown north-central Nebraska to be an island of higher values during most of the fall and winter. In

Sand Hills boundary is bold black line.



National Climatic Center, 1982

9° Minimum Temperature — 35° Maximum Temperature

Fig. 2-7. Maximum and minimum January temperatures, degrees F (1951-1980 normals).

Sand Hills boundary is bold black line.

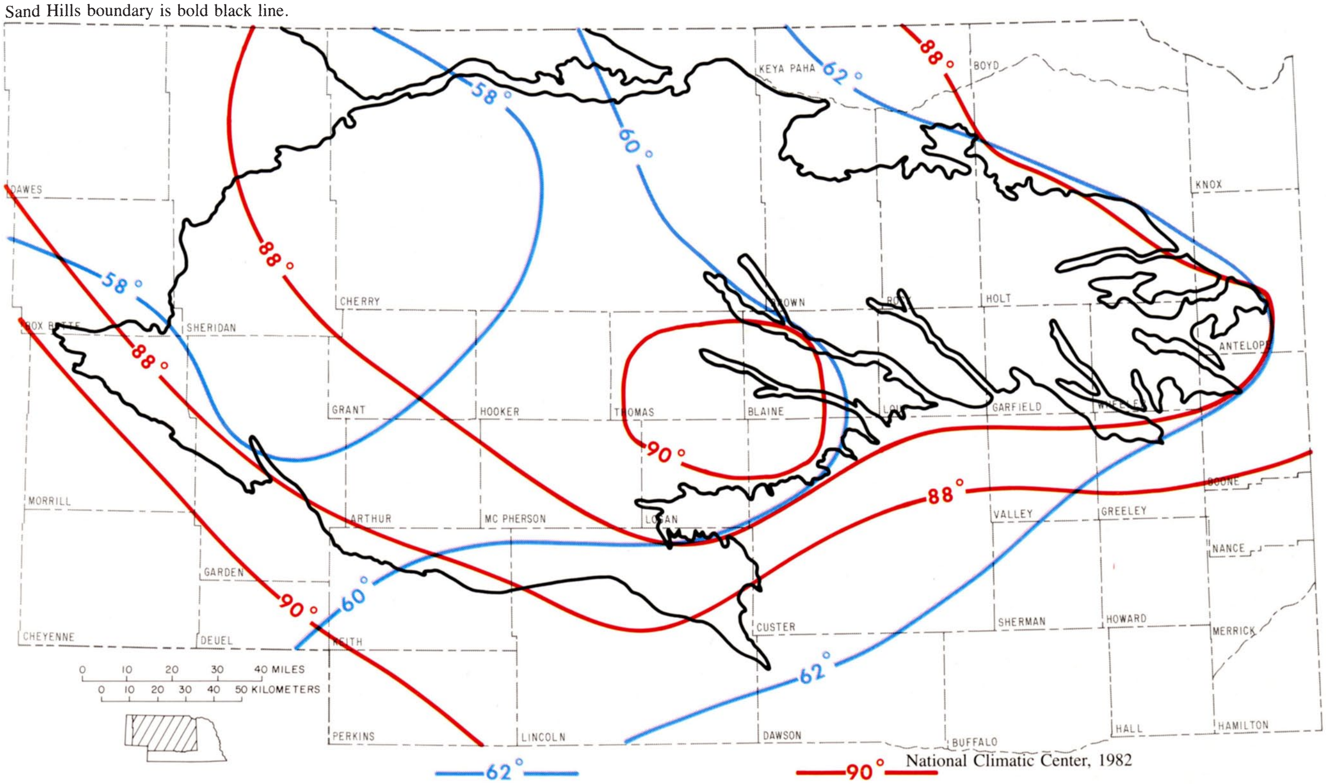


Fig. 2-8. Maximum and minimum July temperatures, degrees F (1951-1980 normals).

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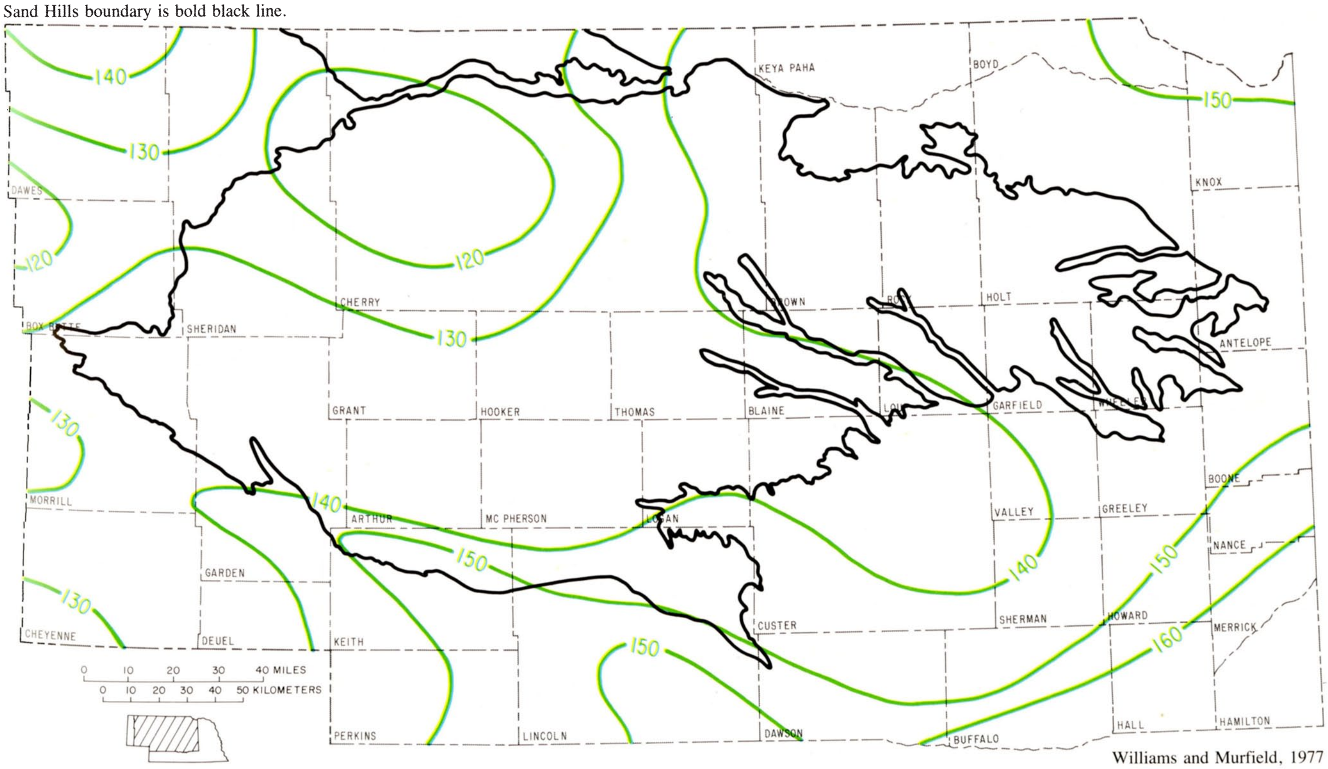


Fig. 2-9. Average annual freeze-free days

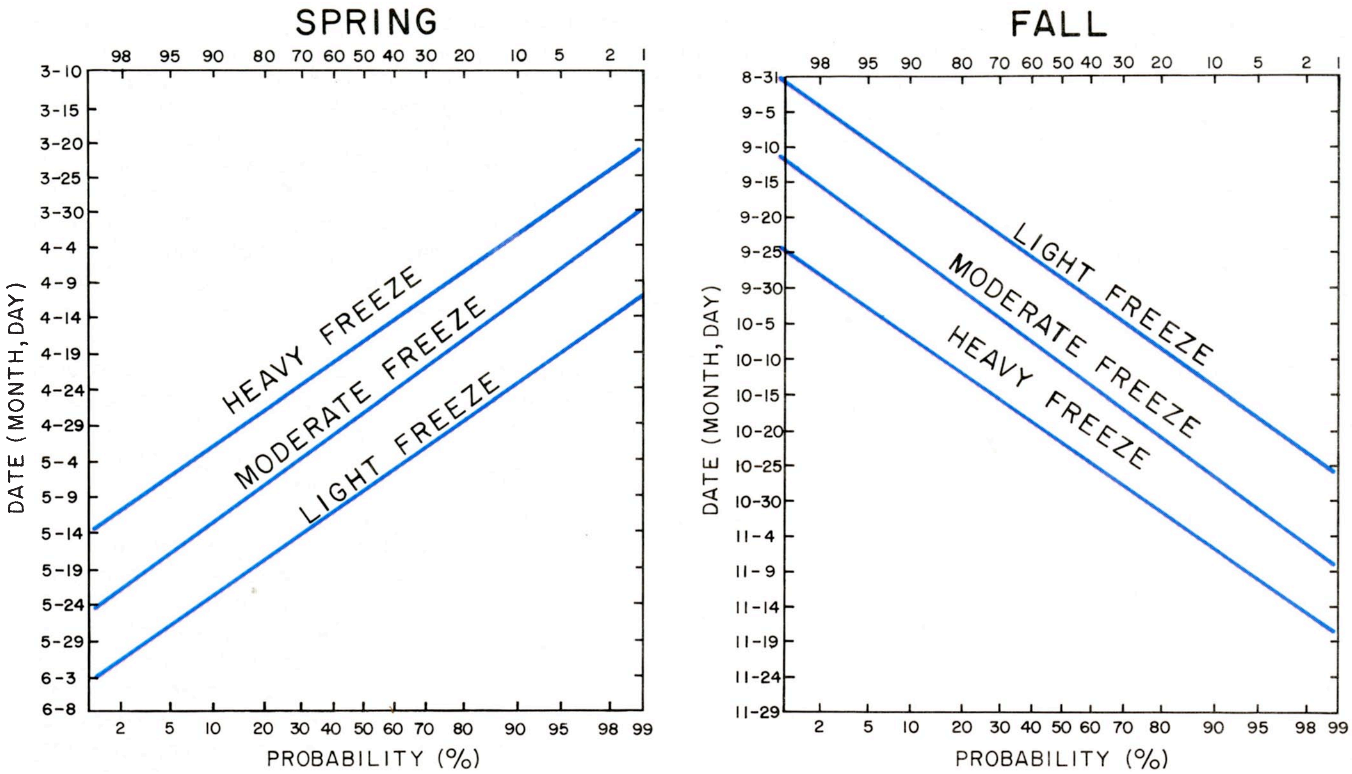
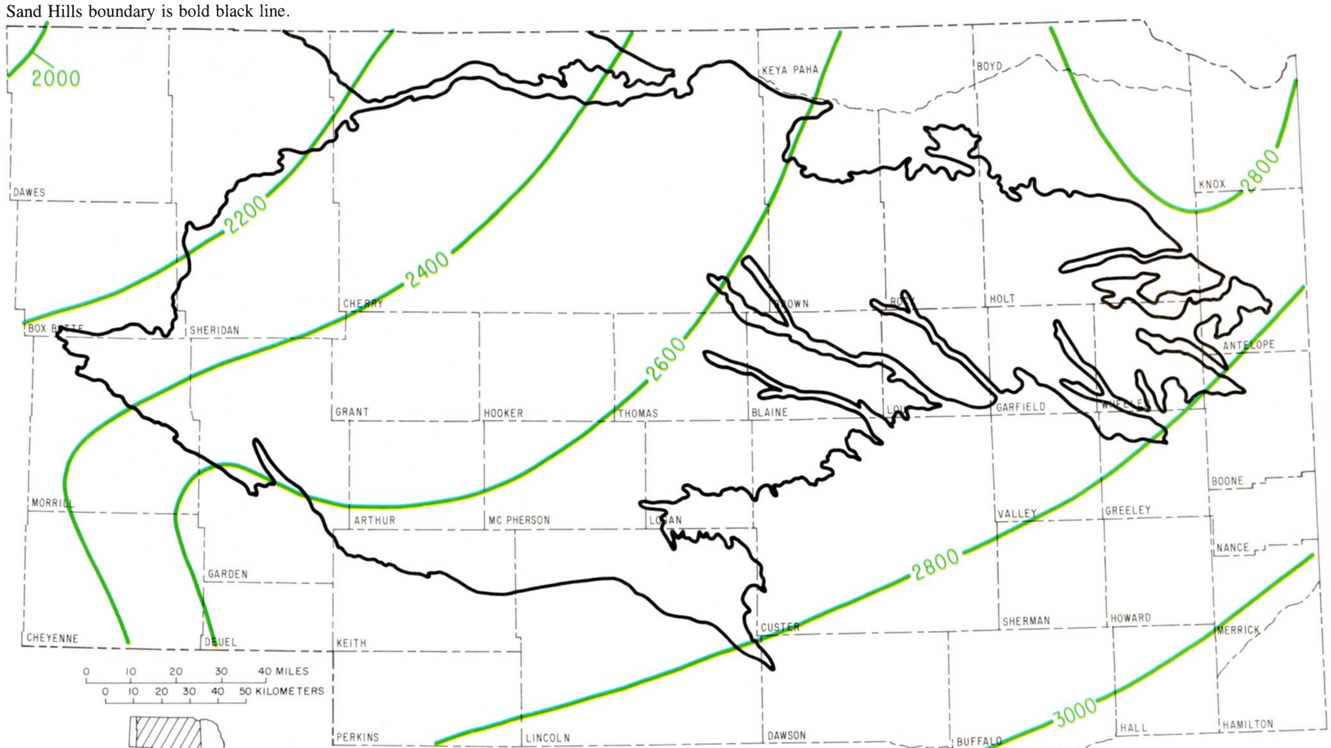


Fig. 2-10. Probability of spring and fall freeze at Valentine on or before specific dates (from Neild, 1973).

Sand Hills boundary is bold black line.



Williams and Murfield, 1977

Fig. 2-11. Average annual growing season, in degree days (above 50 degrees F).

each month between November and February, these "island highs" occur with values consistently at 66 percent of possible sunshine. This pattern returns in the summer months of July and August with values of about 76 percent.

The annual average for daily global solar radiation on a horizontal surface is depicted in figure 2-12. The sun's energy can be expressed in terms of how much energy is received per day on a 1-square-meter area at the earth's surface. As a point of reference, it would take approximately 25 megajoules (MJ) to evaporate one centimeter (cm) of water from a 1-square-meter area (25 MJ/m^2). The values shown in figure 2-12 range from slightly less than 17 MJ/m^2 in the southwest to less than 16 MJ/m^2 in the northwest. This means the average solar energy is sufficiently large to evaporate 0.6 to 0.7 cm of water per day. (To convert MJ/m^2 to BTUs/m^2, multiply by 948.69.)

The occurrence of high temperatures during the summer season is common and presents a significant hazard to the livestock in the Sand Hills. Temperatures above 80 degrees F, especially when accompanied by high relative humidity, are particularly serious. These conditions result in a higher body temperature, higher respiration rate, rapid heartbeat, and consequently, low feed efficiency in meat animals and milk-producing dairy cattle (Williams and Murfield, 1977). The problem is most obvious in the southeastern Sand Hills, where the average number of days exceeding 80 degrees F is slightly less than 100 (fig. 2-13). The problem is usually less serious in the northwest.

Wind

The speed of wind affects how warm or cool we feel. With no wind, all living beings lose body heat when introduced to a cold environment. When winds blow, the rate of heat loss will be dramatically increased under the same environmental conditions. In fact, a 10 mph wind at 20 degrees F causes a loss of heat equivalent to what would occur at 3 degrees F with a low windspeed. This phenomenon has led to the creation of a wind-chill index. This index is an expression of how cold the air would have to be to produce an equivalent temperature effect if wind were not present.

Hourly wind-chill index values for a 48-hour period at Gudmundsen Ranch in the western Sand Hills are plotted in figure 2-14. For comparison, the air temperature and wind speed are also presented in this figure. The air temperature drops below zero three times during this 48-hour period. In these three instances, differences in windspeed cause dramatic differences in the wind chill. The second time the air temperature dropped below zero was actually one of the more comfortable intervals in this 48-hour period because light winds caused essentially no chilling effect. Such examples point out the major role that wind plays in human and animal comfort.

Wind patterns vary considerably in the Sand Hills because of the effect of topography. The downwind (lee) side of the hills is sheltered from the winds that act on the upwind side. During blizzards, livestock and large wildlife seek shelter on the lee side of the hills. The wind chill is relatively less severe and thereby increases their comfort and in extreme cases their chance of survival.

Although the wind patterns will vary considerably with terrain, the general wind characteristics can be seen by examining measurements taken from a representative site. Figure 2-15 is a wind rose for North Platte. The records from North Platte, located in a wide river valley on the southern edge of the Sand Hills, are typical. Winds are controlled to a large extent by the passage of frontal systems. Winds are generally southerly

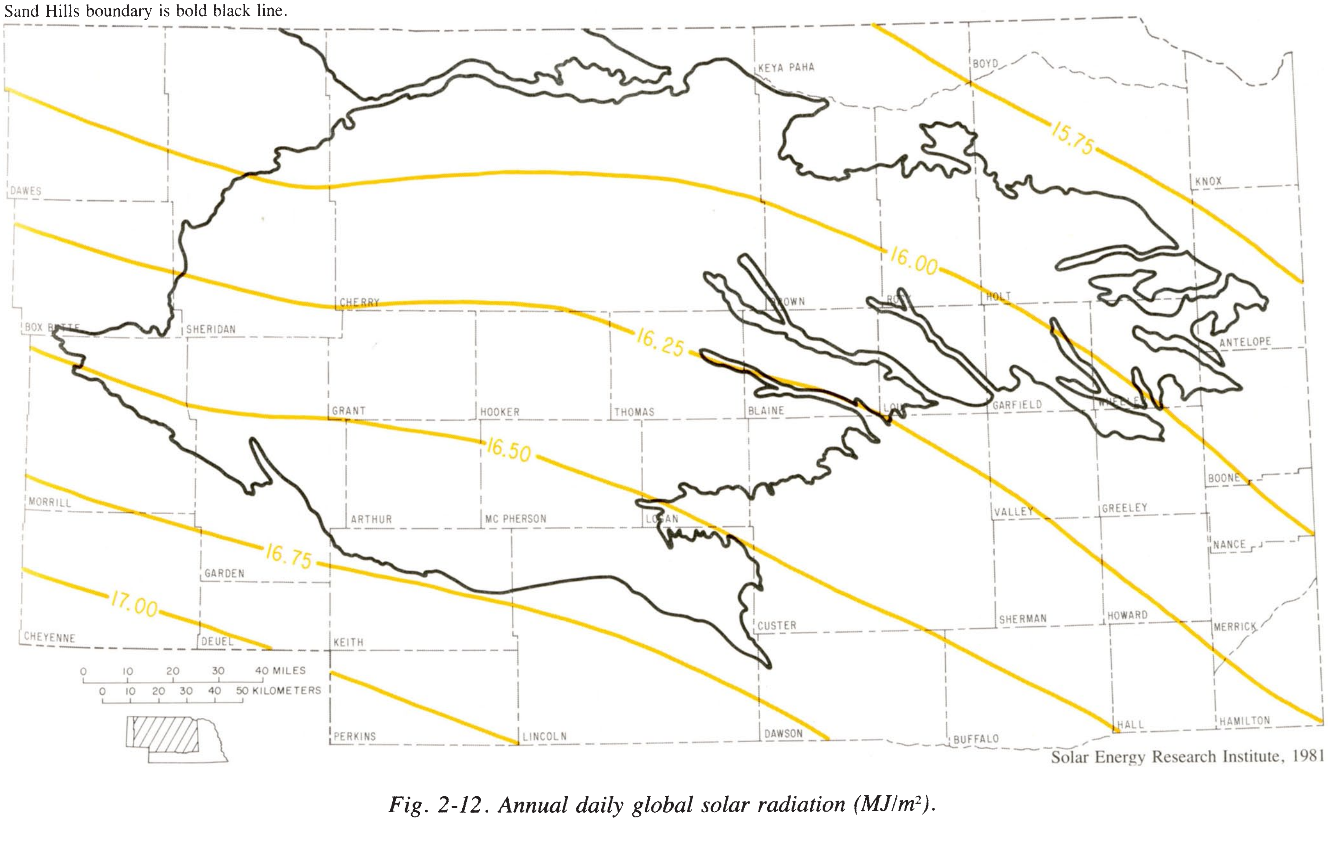


Fig. 2-12. Annual daily global solar radiation (MJ/m^2).

Sand Hills boundary is bold black line.

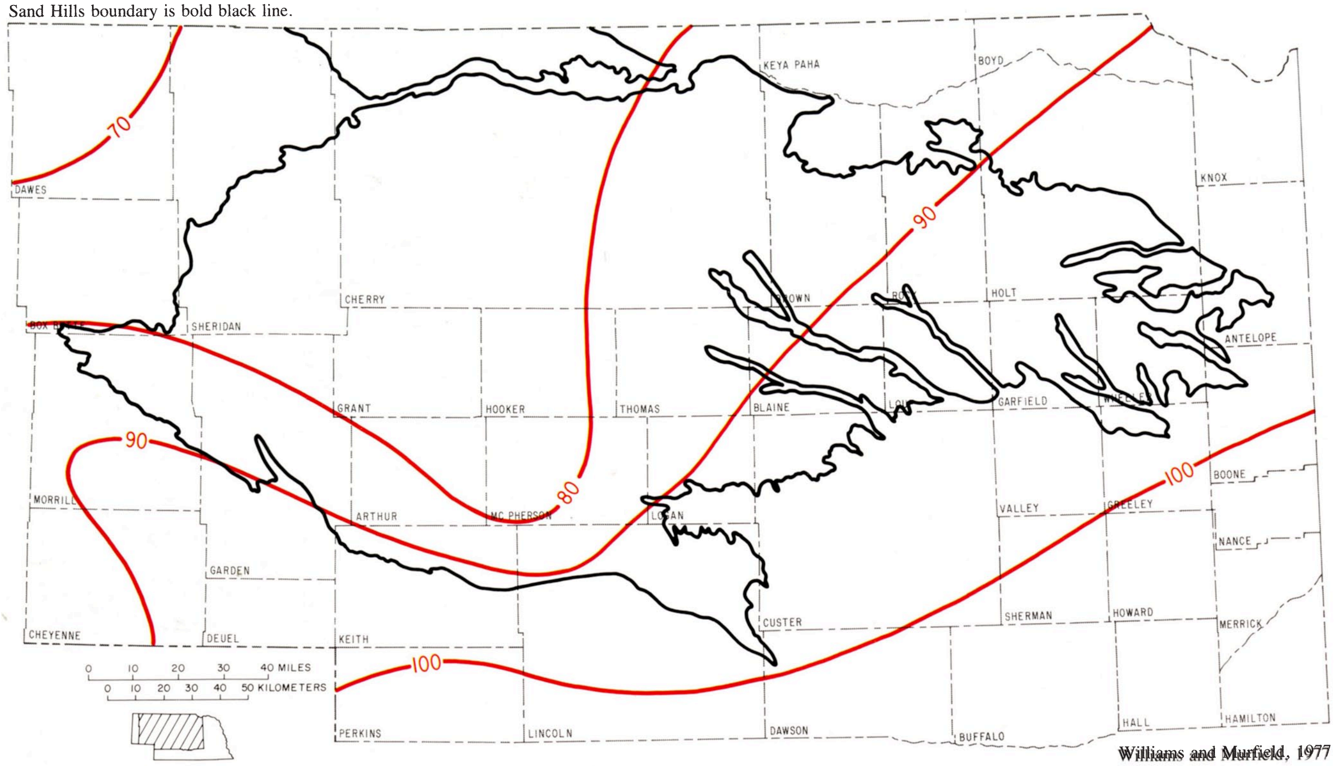


Fig. 2-13. Average annual number of high-temperature stress days.

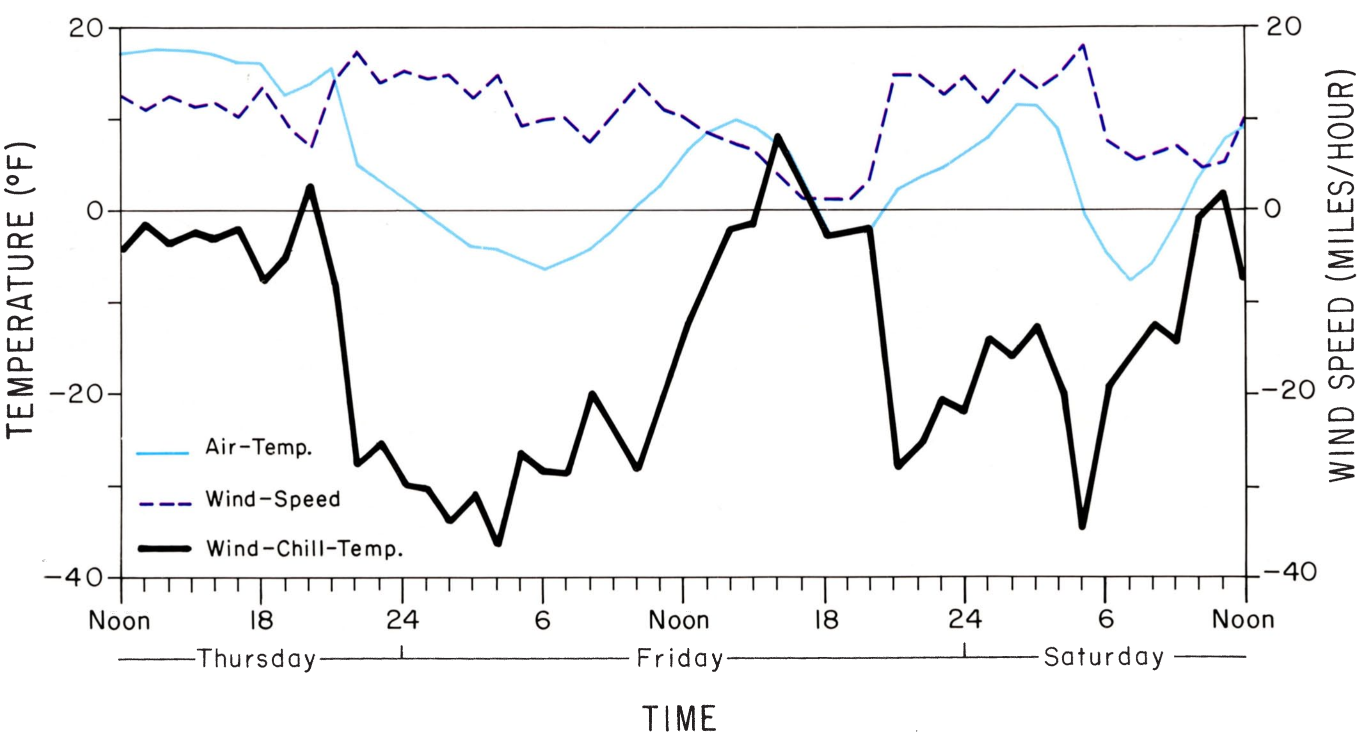


Fig. 2-14. Wind-chill, Gudmundsen Sandhills Laboratory.

Sally Schuff

Wind-blown sand derived from an active blowout

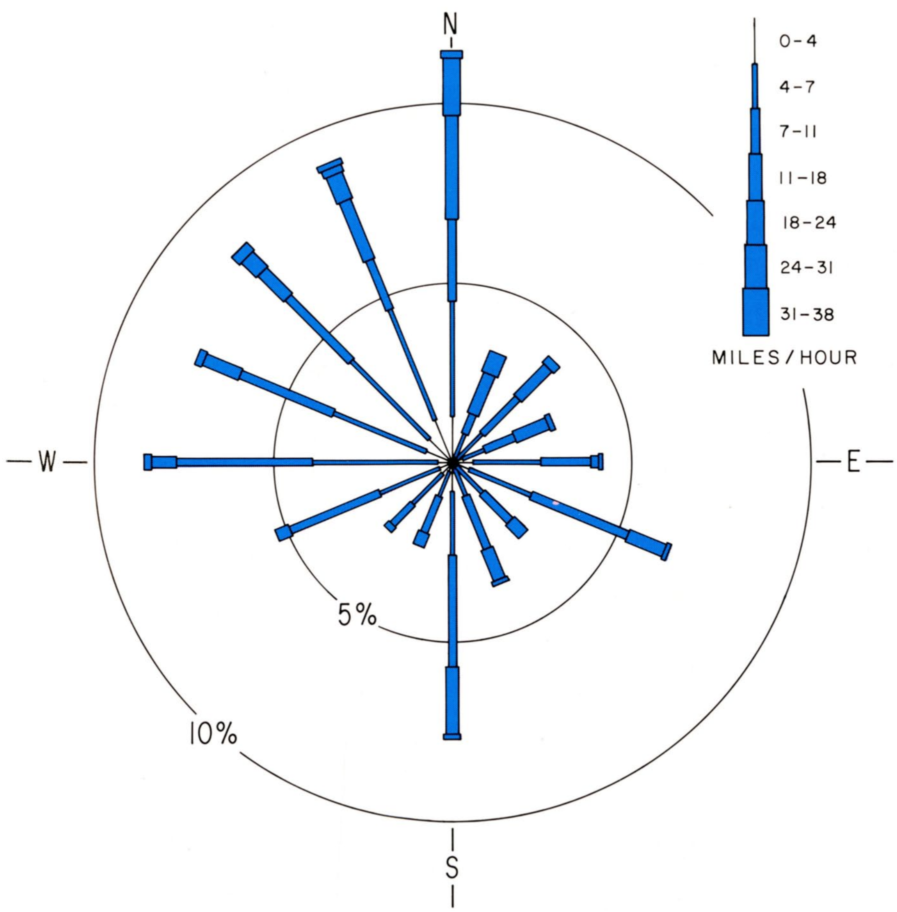


Fig. 2-15. Wind rose, North Platte.

before the frontal systems pass and from the northwest after a cold front passes. The wind rose shows the percent of time that winds are from each of 16 directional sectors and the width of the bars gives the magnitude of these winds. The wind rose shows that the greatest frequency (slightly more than 10 percent) is associated with wind from the north (N). The wind is out of the following directions between 5 and 10 percent of the time: NNW, NW, WNW, W, WSW, and S. Winds blow from the other directions less than 5 percent of the time. Prevailing winds have a northerly component in winter and a southerly component in summer.

Evapotranspiration

The concentration of precipitation during the summer months corresponds closely with the needs of native vegetation and agricultural crops. The moisture balance for four locations—Ewing, Valentine, Halsey, and Alliance—is presented in figure 2-16. Note the annual cycle in the distribution of precipitation (P). On average, the precipitation minimum occurs during the winter months and the maximum during May or June, depending on the location within the region. The atmospheric demand for moisture is referred to as the potential evapotranspiration (PE). Potential evapotranspiration can be defined as the combined total evaporation of free-standing water and the transpiration of moisture from the soil through vegetation. The Sand Hills vegetation undergoes a period of dormancy, so evapotranspiration is zero or negligible during the winter months. Evapotranspiration reaches its maximum in July for all locations shown in figure 2-16. During the winter the occurrence of water on the surface (caused by the formation

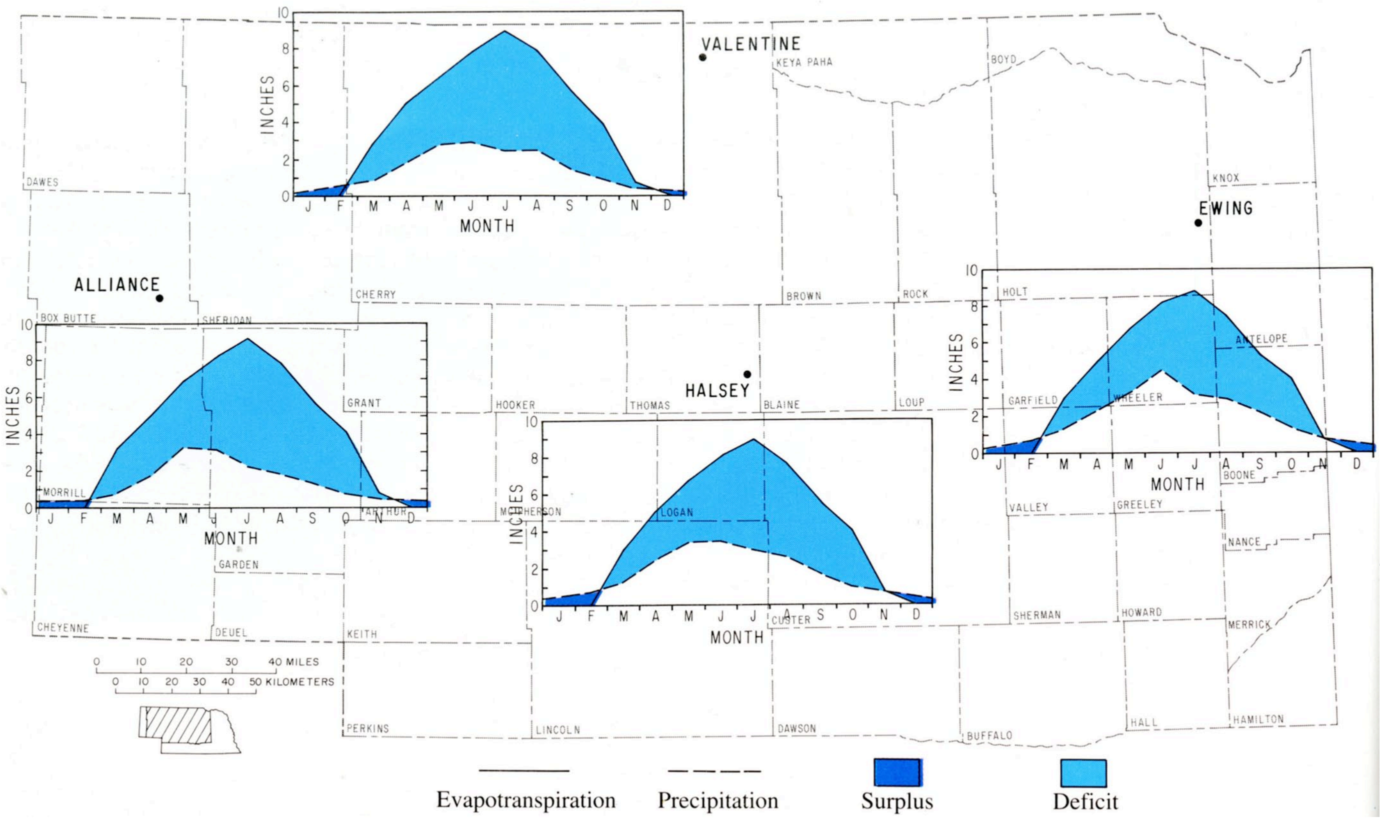


Fig. 2-16. Moisture balance for Alliance, Halsey, Valentine, and Ewing.

of frost and condensation) is thought to be balanced by evaporative losses from the surface, although precise measurements are not available.

A comparison of the annual cycles of potential evapotranspiration and precipitation indicates that, under average conditions, Sand Hills locations experience a period of surplus moisture (supply exceeds demand) during the period from late fall to early spring. A deficiency of available moisture (demand exceeds supply) occurs during the remainder of the year. These conditions are characteristic of all locations in Nebraska, not just those in the Sand Hills, and help to explain the considerable irrigation in the state.

On average, summer precipitation is inadequate to meet the atmospheric evaporative demand in the Sand Hills. However, grasses indigenous to the Sand Hills are well suited to the environment, making good use of the stored soil moisture and spring precipitation. The distribution of grass species between the tops of the dunes and the interdunal valleys is largely explained by soil characteristics, the availability of soil moisture, and other climatic factors such as temperature, as discussed by Weaver (1965).

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